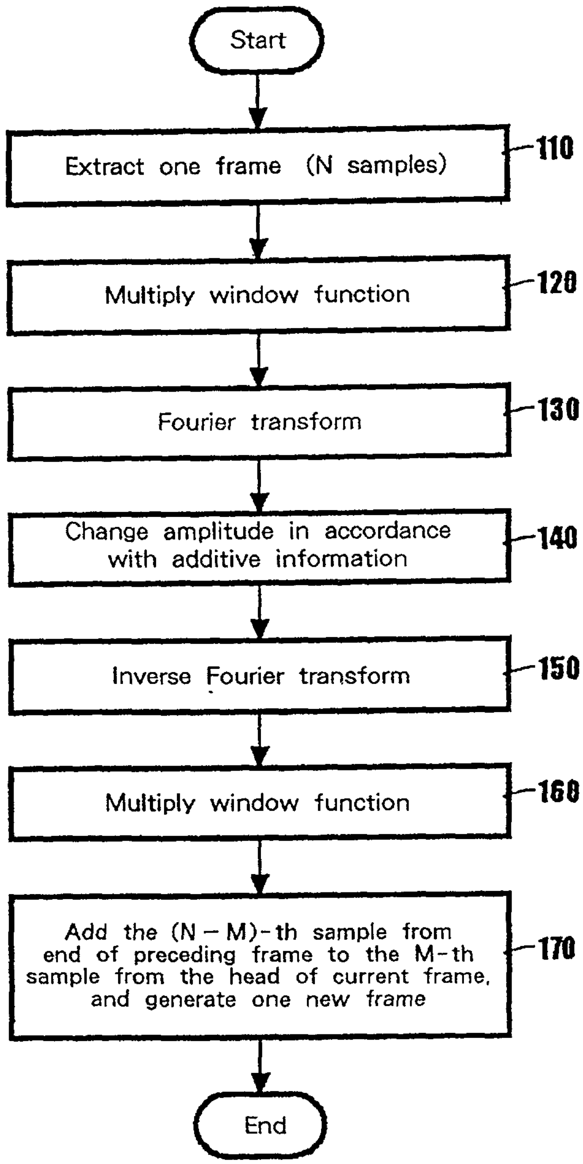

Start
Extract one frame (N samples)
110
Multiply window function
120
Fourier transform
130
Change amplitude in accordance with additive information
140
Inverse Fourier transform
150
Multiply window function
160
Add the (N − M)-th sample from end of preceding frame to the M-th sample from the head of current frame, and generate one new frame
170
End

Fig. 1

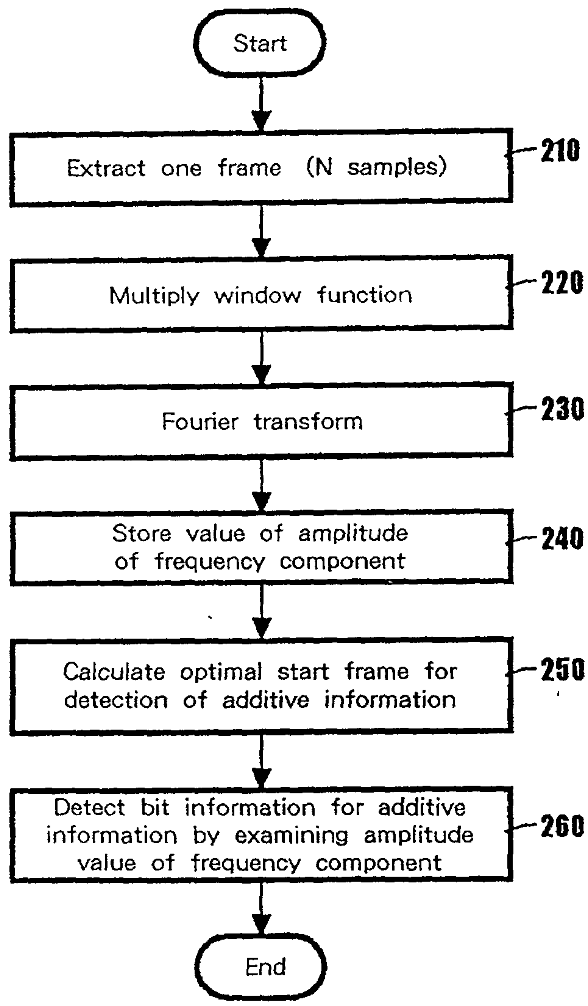
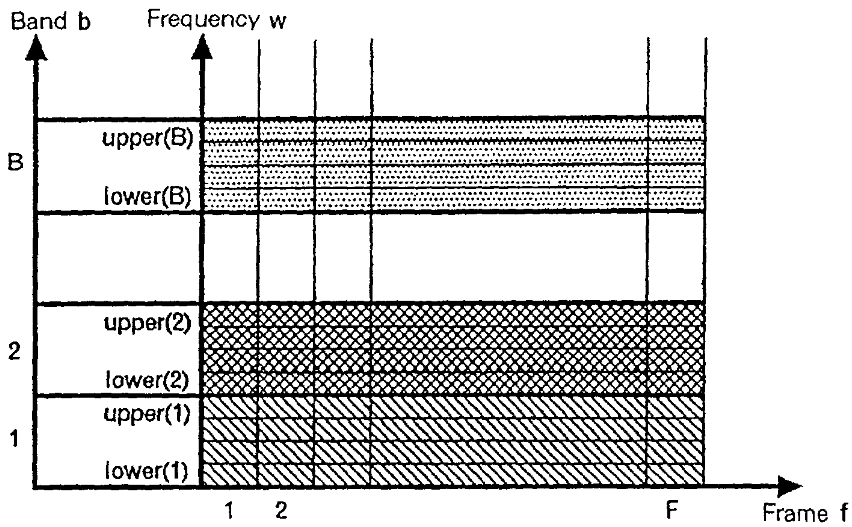
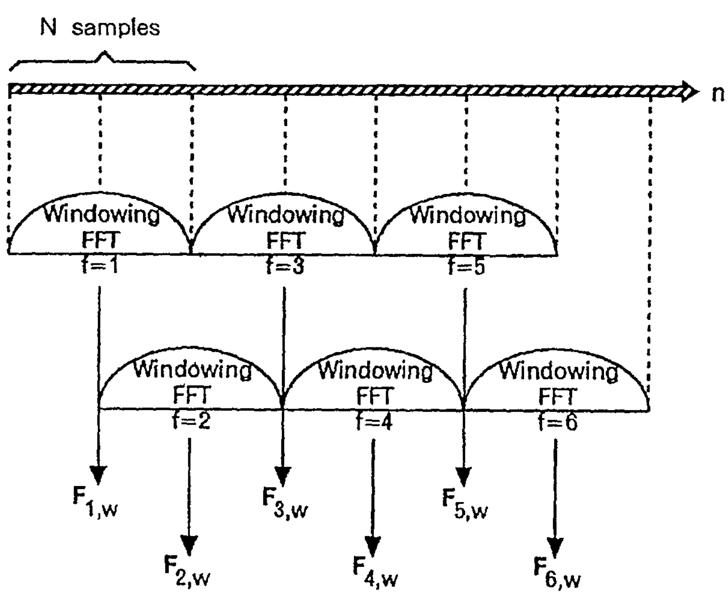

Start
Extract one frame (N samples)
210
Multiply window function
220
Fourier transform
230
Store value of amplitude of frequency component
240
Calculate optimal start frame for detection of additive information
250
Detect bit information for additive information by examining amplitude value of frequency component
260
End

Fig. 2



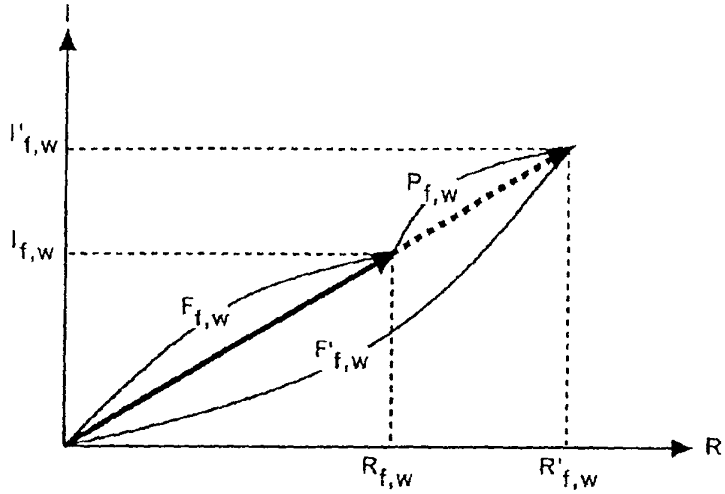
Time axis and frequency axis

Fig. 3



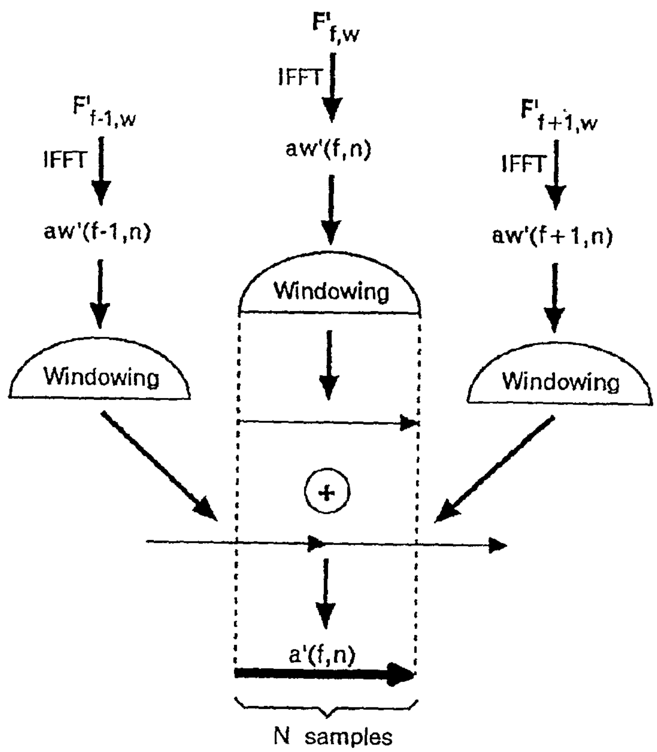
Frame

Fig. 4



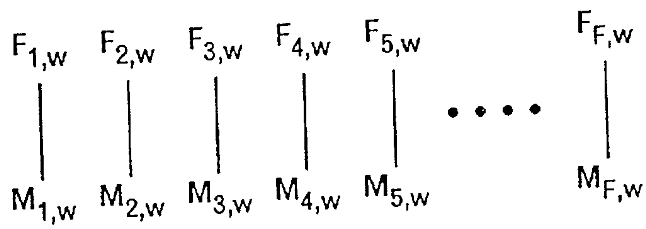
Amplitude change

Fig. 5



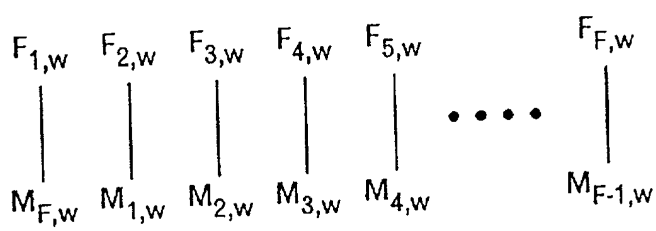
Perform windowing, superimposing frames and outputting them along a time axis

Fig. 6



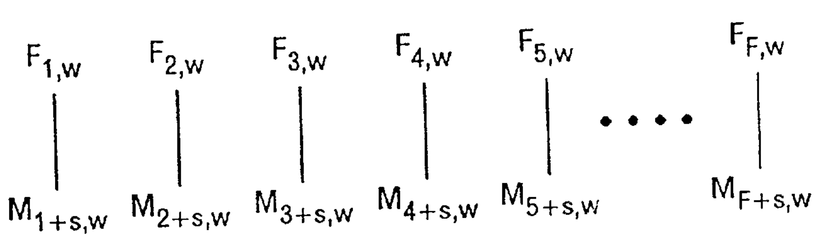
No frame shift

Fig. 7



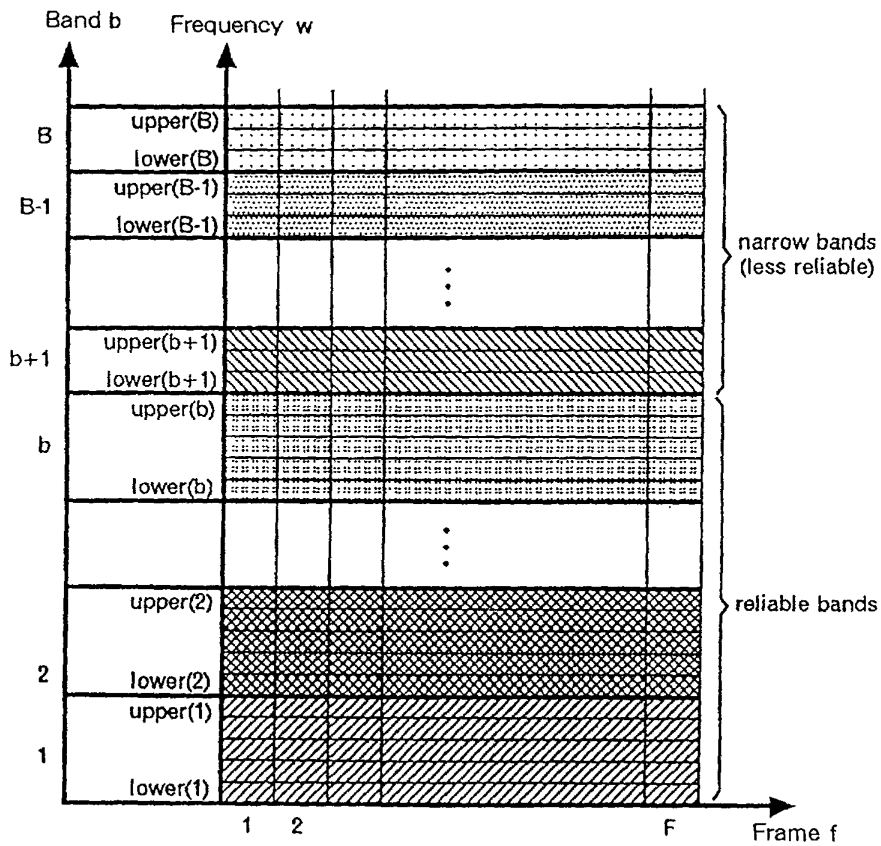
Shift one frame

Fig. 8



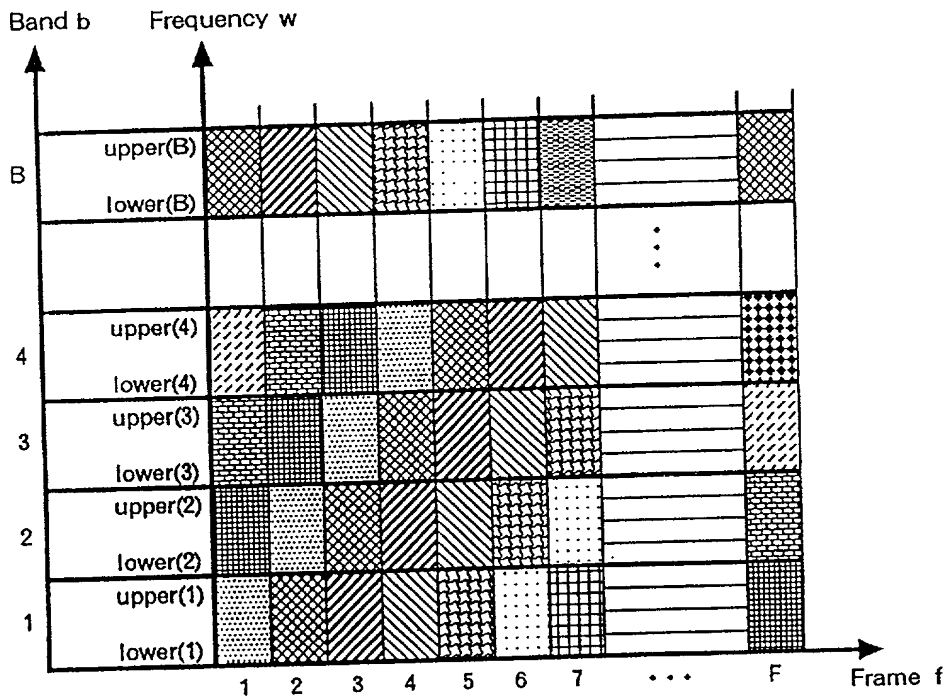
Cycle synchronization

Fig. 9



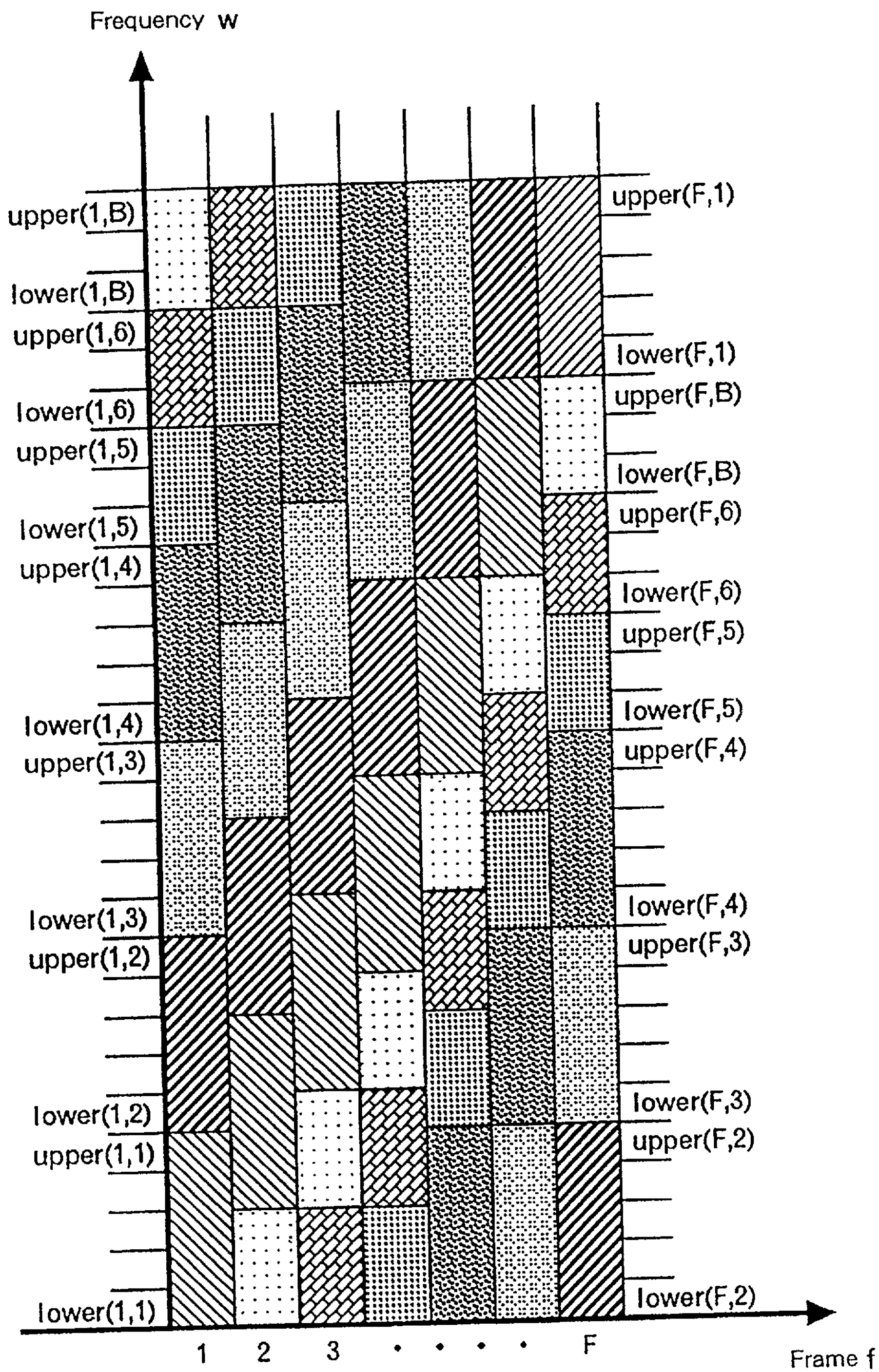
Provide a difference in reliabilities

Fig. 10



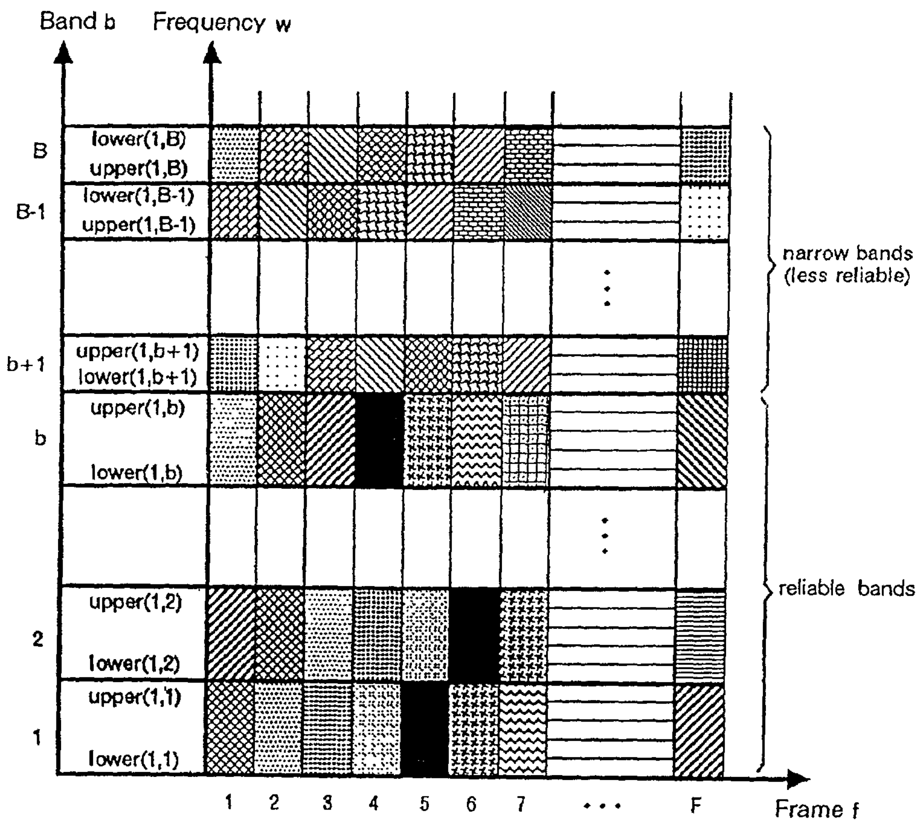
Diagonal embedding

Fig. 11



Discrimination and equalization of reliability

Fig. 12



Diagonal embedding whose speed can be increased

Fig. 13

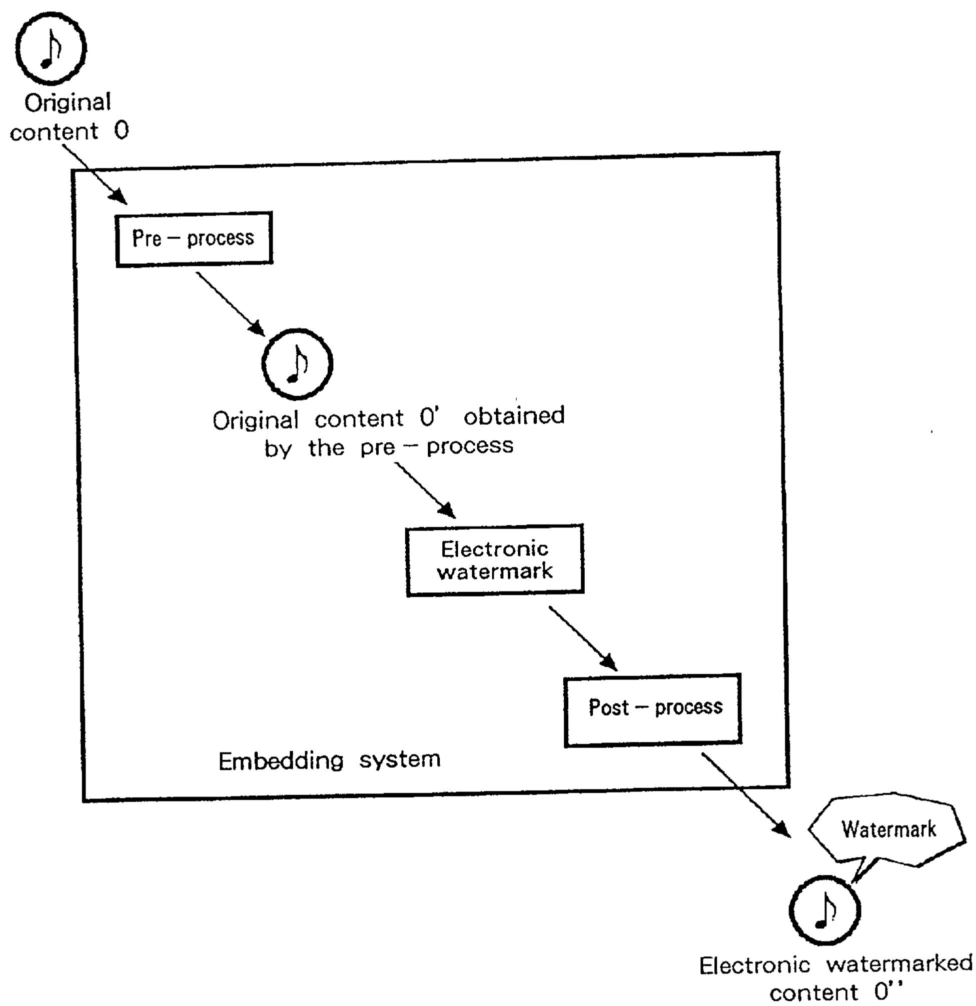

Original
content 0
Pre – process
Original content 0' obtained
by the pre – process
Electronic
watermark
Post – process
Embedding system
Watermark
Electronic watermarked
content 0''

Fig. 14

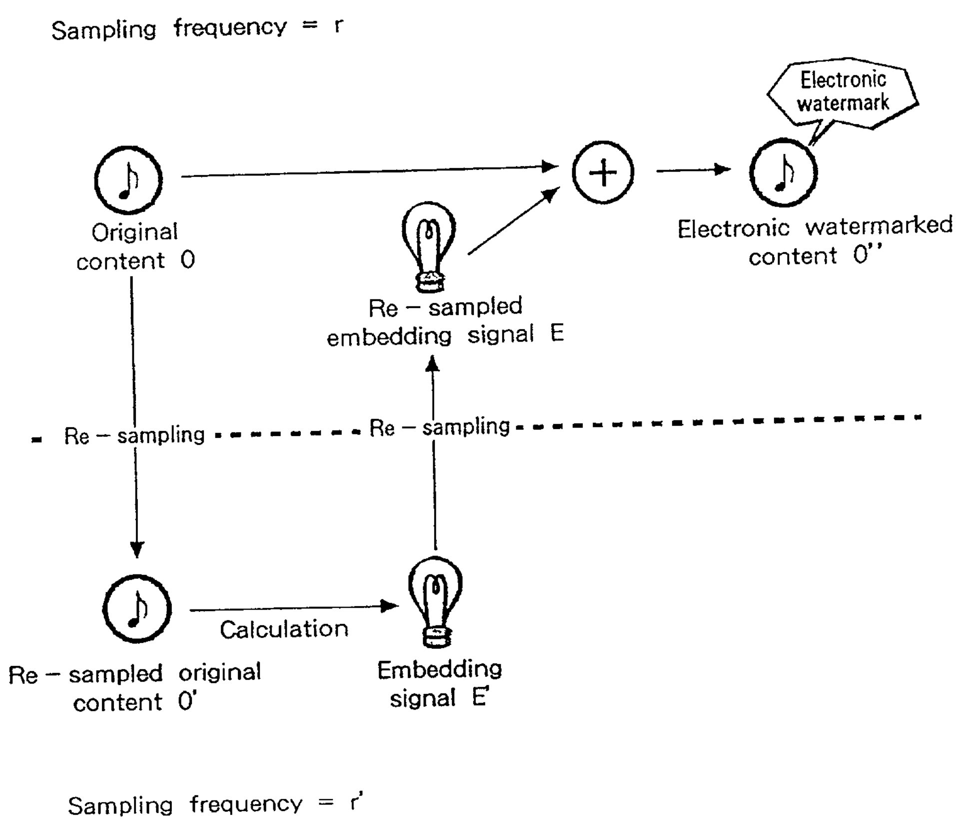

Sampling frequency = r
Electronic watermark
Original content 0
Electronic watermarked content 0''
Re – sampled embedding signal E
Re – sampling
Re – sampling
Calculation
Re – sampled original content 0'
Embedding signal E'
Sampling frequency = r'

Fig. 15

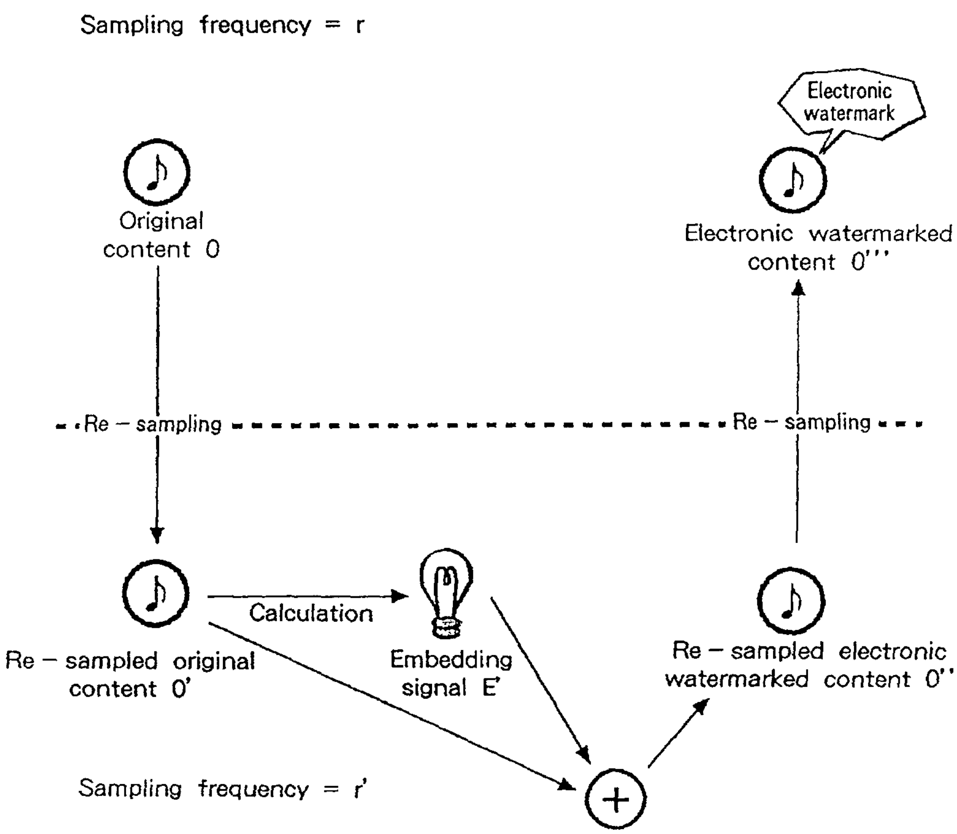

Sampling frequency = r
Electronic watermark
Original content 0
Electronic watermarked content 0'''
Re – sampling
Re – sampling
Calculation
Re – sampled original content 0'
Embedding signal E'
Re – sampled electronic watermarked content 0''
Sampling frequency = r'

Fig. 16

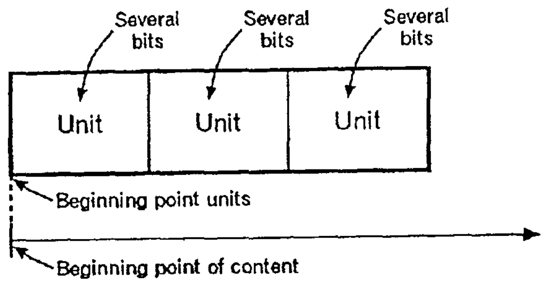


Fig. 17

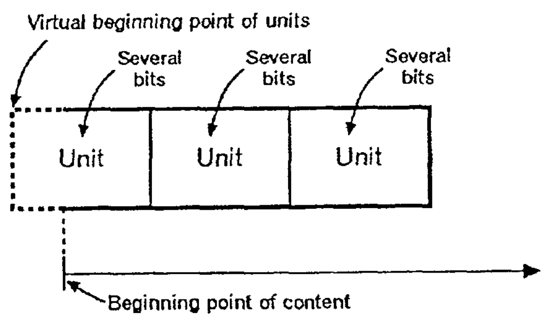
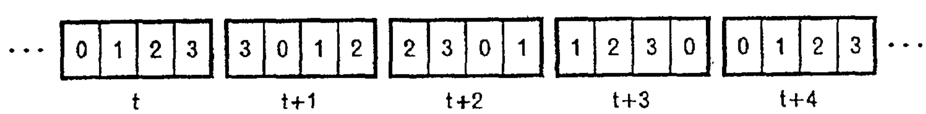
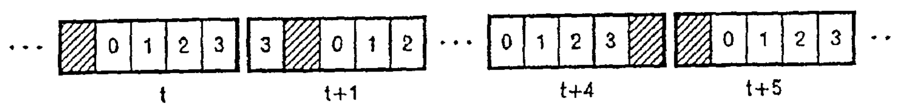


Fig. 18



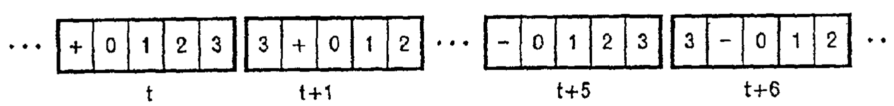
Example of bit information embedding positions being changed as time elapses

Fig. 19



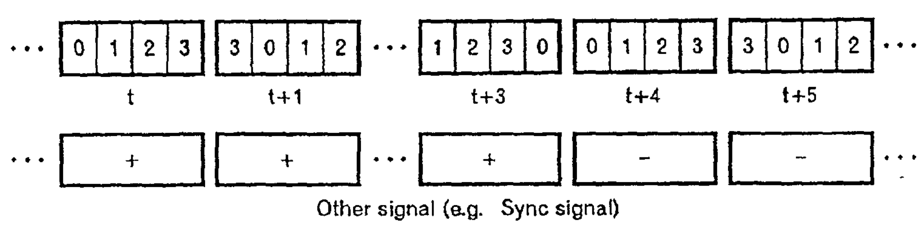
Insertion of non − information embedding positions

Fig. 20



Embedding of information for which the bit is inverted at cycle 2T

Fig. 21



Use of information other than bit information

Fig. 22

DFT	Discrete Fourier Transform. Process for obtaining the frequency component of digital audio data.
FFT	Fast Fourier Transform. Algorithm for the fast performance of a discrete Fourier transform. The same effect can be obtained when FFT in the specification is replaced by another DFT; however, the processing time is increased.
IFFT	Inverse Fast Fourier Transform.
Time domain	Space, before FFT, where the PCM wave of digital audio data is present.
Frequency domain	Space where a frequency component is present after the FFT has been performed for digital audio data.
Frame	An embedding system and a detection system in this invention extract a constant number of samples from digital data, and perform a FFT for the samples. Digital data consisting of a constant number of samples is called one frame.
Window	In this invention, before a FFT is performed or after an IFFT is perdormed for embedding or detection, digital data is multiplied by a specific function. This process is called "windowing", and the function to be multiplied is called a "window function". Basically, a sine function is employed as the window function; however, another function that satisfies a condition may be employed.
Additive information	Information to be embedded in digital data: copyright information, copying and reproduction permission conditions, music names or words. First, the information is represented as a bit sequence consisting of 0s and 1s, and then, by replacing 0s by −1s, the obtained information is actually used for embedding.
Original sound	Digital audio data in which no information has been embedded yet.
Embedding signal	A signal equivalent to a digital data change during the embedding process. This term is used for the time domain and the frequency domain.
Frequency band	In this invention, all the frequency bands are sorted into several frequency bands, and one bit is embedded in each band (there are exceptions).
Mask	A sequence of +1s and −1s that is acknowledged by the embedding system and the detection system. This determines whether the frequency component of digital data should be increased or decreased in the embedding process. Also in the detection process, the mast determines whether the frequency component should be additive or subtracted.
Frame synchronization	This process is required for conventional frequency domain detection; however, it is not required for the detection performed by this invention. A process for determining the range of digital data that was used as a frame in the embedding process.
Bit detection value	A numerical value used for the detection process to determine each bit of additive information embedded in digital data.
Cycle synchronization	One of the processes used for the invention, for determining the first frame.
Frame shift	A distance between the first frame obtained by the FFT in the detection process and the first frame in the embedding process. This shift is unknown at the beginning of the detection process.

Table. 1

N	The number of samples included in one frame.
n	An index used to represent the position of a sample. A positive or negative integer.
B	The number of bits of additive information to be embedded.
b	An index used to represent the position of a sample. A natural number B or smaller.
W	The number of frequencies used for embedding.
w	An index used to represent the position of a frequency. A natural number W or smaller.
F	The number of frames used for one embedding.
f	An index used to represent the position of a frame. A natural number F or smaller.
a(f,n)	The n-th sample value in a frame f of digital audio data. Since frames are overlapped, $a(f+1,n) \equiv a(f,n+N/2)$ $(0 < n \leqq N/2)$. After the embedding, a' (f,n) may be employed.
aw(f,n)	The n-th sample value in a frame f after the windowing of digital audio data. After the embedding, aw' (f,n) may be employed.
w(n)	Window function.
lower(b)	The minimum frequency in a frequency band in which the b-th bit is to be embedded.
upper(b)	The maximum frequency in a frequency band in which the b-th bit is to be embedded.
CB	A sequence of additive information to be embedded. Constituted by CB_b.
CB_b	The b-th value of additive information to be embedded. A value of +1 or −1.
C	A sequence of additive information to be embedded. A frequency is used as a subscript.
C_w	A value of additive information to be embedded at frequency w. Either a value of +1 or −1
M	A matrix of masks having F rows and W columns.
$M_{f,w}$	Mask for frame f and frequency w. A value of +1 or −1. This may be employed as the abbreviation $M_{f,w}(C)$.
$M_{f,w}(C)$	Mask for frame f and frequency w, used for embedding additive information C. A value of +1 or −1.
$\mathbf{F}_{f,w}$	A frequency component vector for frame f and frequency w. Includes a real number component and an imaginary number component
$\mathbf{F}'_{f,w}$	A frequency component vector after the embedding.
$F_{f,w}$	An amplitude for frame f and frequency w. F' may be employed after the embedding.
$I_{f,w}$	An imaginary number component for frame f and frequency w. I' may be employed after the embedding.
$R_{f,w}$	A real number component for frame f and frequency w. R' may be employed after the embedding. $F_{f,w} = \lvert \mathbf{F}_{f,w} \rvert = \sqrt{R_{f,w}^2 + I_{f,w}^2}$ is established.
$\Delta \mathbf{F}_{f,w}$	An embedding signal of frame f and frequency w. A vector in a frequency domain. $\mathbf{F}'_{f,w} = \mathbf{F}_{f,w} + \Delta \mathbf{F}_{f,w}$
$\Delta I_{f,w}$	The imaginary number component of an embedding signal of frame f and frequency w. $I'_{f,w} = I_{f,w} + \Delta I_{f,w}$
$\Delta R_{f,w}$	The real number component of an embedding signal of frame f and frequency w. $R'_{f,w} = R_{f,w} + \Delta R_{f,w}$
$P_{f,w}$	Permissible range obtained for frame f and frequency w by using an auditory psychological model
C_b	A detection value for b-th additive information. A floating point number.
$C_b(s)$	A detection value for the b-th additive information while assuming an s frame shift.
$C_{+,b}$	A detection value obtained while assuming +1 is embedded in the b-th additive information. A floating point number
$C_{+,b}(s)$	$C_{+,b}$ while assuming an s frame shift.
$C_{-,b}$	A detection value obtained while assuming −1 is embedded in the b-th additive information. A floating point number.
$C_{-,b}(s)$	$C_{-,b}$ while assuming an s frame shift.
S_s	A cycle synchronization value while assuming an s frame shift. A floating point number
T_b	A threshold value for determining the reliability of a bit. A constant set in advance
TWM	A threshold value for determining the presence of a watermark. A constant set in advance.

Table. 2